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A VACUUM PNEUMATIC PROCESS FOR FILLING LARGE DRY CHEMICAL FIRE EXTINGUISHERS

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CONTENTS

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ABSTRACT

A pneumatic conveying system has been developed for filling large fire extinguishers with dry chemical powder. The system is intended particularly for air stations and similar field establishments; it could even be used for reloading extinguishers at the site of a fire. The essential components are a 1-1/2 horsepower vacuum cleaner and an especially designed device which is used in place of the extinguisher fill cap which separates the powder from the air stream, and also provides entry for a powder level gage stick.

In trials at the Laboratory this system reduced the filling time for a 400-lb. capacity dry chemical "air-lift" extinguisher from 46 to 6 minutes, reduced dusting to a negligible amount, and allowed correct gaging of adequate charge amounts.

The simply designed separator permitted only 3.4% of the total powder weight to be carried over into the bag filter of the vacuum cleaner. This could, of course, be emptied into the shipping can used in the next charge cycle or returned to the charge during the filling process. The segregation represented by these "returnable" fines reduced the specific surface of the extinguisher charge powder only 5%, even if the fines caught by the filter bag were not returned. There is no evidence yet that this change would lower the unit efficacy of the extinguishing powder appreciably.

PROBLEM STATUS

This is a final report on this phase of the problem.

AUTHORIZATION

NRL Problem C08-15
BuWeps SEQ 12-001/652-1/F012-05-04

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A VACUUM PNEUMATIC PROCESS FOR FILLING LARGE DRY CHEMICAL FIRE EXTINGUISHERS

INTRODUCTION

Dating from the time of their original development, the filling and refilling of portable large fire extinguishers of the dry chemical type with their finely powdered active chemical agents has been a wasteful, slow, and disagreeable task. The comparatively crude system of pouring the flow-resisting powder from a 50 lb. laboriously hand-supported pail into a funnel, shaped to fit the small filling aperture size of the extinguisher, has been the only filling method available. Steady control of flow of the powder with this scheme is almost impossible. Characteristics of fineness and intermittent flowability impart to these agents a proclivity toward overflowing, spilling and taking flight into the air. The problem is directly proportional to the wind velocities encountered at the time of charging, which must be conducted out of doors to prevent serious contamination of inside areas. Not only are nearby personnel subjected to the dust nuisance with its dangerous ingestion problems, but all surrounding equipment and downwind areas become liberally coated with chemically active powder. Frequently, if outside weather conditions are on the damp side, the deleterious exposure of powder to water droplets or high humidity conditions occurs during the long filling process presently used.

The recent phenomenally successful Class B fire fighting use of potassium bicarbonate dry chemical (Purple-K-Powder) originated by the U. S. Naval Research Laboratory in 1958, has increased the utility of the large, crash-rescue "air-lift" extinguisher containing a charge of 400 lbs. of this powder. Portable wheeled extinguishers with a 150 lb. load of powder are also in wide use at Naval Air Stations. Procurement of several snow-vehicle mounted dry chemical extinguishers containing 4000 lbs. of agent each, for Antarctic use has been started. These units will use the new multipurpose phosphate dry chemical for universal fire fighting purposes. Research is underway to determine the relative effectiveness of 7,500-pound containers of dry chemical supplying mechanized turret nozzles for mass application on aircraft crash fires. Obviously, some improved mechanized, dust-free procedures for rapidly loading these large fire extinguishing chemical containers are urgently needed if maximum utility is to be obtained.

Although no details of the process seem to be available, it has been said that the larger manufacturers of dry chemical extinguishers utilize a vacuum filling process in their assembly lines of equipment up to and including those containing 30 lbs. of powder.

OPERATING PRINCIPLES INVOLVED

Quite early in the consideration of solutions to this problem, it was decided that pneumatic conveying offered the simplest, cheapest and thus the best, possibility of transporting this powdered material from its shipping container to an extinguisher shell. There are many industrial processes using this method, whereby finely divided dry materials are suspended in a moving air stream and borne to the desired point. At this point, the air and powdered (or granular) material must be separated, the powder being deposited and the air released to the atmosphere. Normally, this separating equipment is quite elaborate, usually consisting of a primary "cyclone" separator and one or more secondary bag filters. These devices are necessary in systems operating continuously 24 hours a day, and where no allowable discharge of powder to atmosphere is permitted. It was judged that for large fire extinguisher filling operations, the requirements were not as stringent, and a simpler separating arrangement could suffice.

The practicality of a simple extinguisher filling system for field usage would depend on the degree of separation or powder deposition that could be obtained at or within the powder container with a minimum of special equipment. Also, it was desired to have a minimum degree of powder classification, i.e., a minimum separation of particle sizes in the powder by "carrying over" an excessive amount of fines in the air stream.

SYSTEM DESIGN

The limited distances of travel and necessary lift heights of material in this particular application of pneumatic conveying did not require critical determinations of air and material losses, nor was a high energy requirement involved. The most convenient air mover available was an industrial type vacuum cleaner used by the janitor in cleaning the laboratory building. It was built by the Spencer Turbine Co. and designated as "Commercial Vacuum Cleaner, Catalog P-135". Measurements indicated that it would generate a vacuum of 5.7" Hg. and move 90 cfm of air. A four-stage turbine is used in this equipment for moving the air and a conventional bag filter serves as the final air-solids separator.

As mentioned previously, it is essential that a good degree of separation between the air and powder take place at the extinguisher, otherwise the powder will end up in the air moving device. All efforts were devoted to the design of a stream direction changing device for attachment to the large extinguisher at the filling aperture, which would

perform the desired separation. Several trials employing centrifugal action for separation were unsuccessful. However, when the utilization of specific gravity differences, in addition to stream direction changing was tried, a good separation of powder-air mixture was obtained.

A special cap or separator head was designed to fit the threaded fill fitting on the top of the 400 lb. capacity "air-lift" unit. It provided for the powder-air mixture to be introduced in a straight downward direction at the lowest velocity that the diameter of the fill opening would permit. The air outlet was arranged to face at right angles to the direction of powder entry. A cross sectional drawing of the special filling cap showing the construction details is given in Fig. 1. Fig. 2 is a photograph of the exterior of the same cap. A 12-1/2 ft. length of 1-1/2" I. D. reinforced plastic vacuum hose connects the cap to the vacuum cleaner and a second piece of similar hose serves as a pick-up line for inserting into the 50-lb. powder shipping cans. Fig. 3 shows the special fitting designed to fit on the pick-up end of the hose. Its purpose is to loosen the powder around the end of the hose in order to promote better flow and faster powder intake. Fig. 4 shows the complete system in operation. Fig. 5 is a close-up of the interior of a can during its unloading.

OPERATING CHARACTERISTICS

With the arrangement shown in Fig. 4 a test dry chemical filling of the 28.75 inch diameter "air-lift" sphere was made to determine the flow rates and other operating characteristics. A manometer was connected to the ball for measuring the pressure during the runs. The vacuum hose was disconnected after emptying each can in order to check the air flow rate to determine how badly the filter bag on the vacuum cleaner was becoming clogged with powder. Time to empty each 50-lb. pail was also measured. At the conclusion of the tests the amount of powder accumulated in the filter bag was measured. Samples of powder were taken for specific area determinations from the can, the "air-lift" sphere and the vacuum cleaner filter bag.

It was observed during the actual ingestion and pneumatic transportation of powder that the vacuum reading in the ball was approximately 5.1" Hg. (This was subject to some fluctuation as the operation moved the pick-up nozzle in and out of the bulk of powder in the can.) According to the air flow calibration curve, the air intake flow rate was approximately 20 cfm at this pressure condition.

There was no observed drop-off in flow or vacuum during the process of emptying each can. This was taken to indicate no appreciable blockage of the vacuum cleaner filter bag by powder build-up on

its surface during this period. At the start of the run, with a clean filter bag, the air flow rate was measured to be 84 cfm with an unobstructed pick-up nozzle. After picking up one can of powder a similar measurement showed the air flow rate had been reduced to 59 cfm as a result of powder accumulation on the bag's surface. The vacuum cleaner motor was then shut off, which allowed the excess powder to drop from the bag surface into the collector pan below it. On restarting, the air flow had increased slightly to 64 cfm. This procedure was followed for the remainder of the filling operation. The airflow reached an equilibrium point of about 50 cfm after the second can.

The actual rate of powder pick-up varied quite widely. This fluctuation appeared to depend more on the operator's technique in maneuvering the pick-up nozzle than it did on the air flow capacity of the system. This was reflected in the average rate for the first can which was a low rate of 0.43 lbs./sec. with a clean bag, and increased to 1.14 lbs./sec. for the last can, when the bag was in its worst condition of plugging with carried over powder. Each can was rolled on the floor before opening to loosen the contents and to make it easier for the operator to move the pick-up nozzle through the powder. The most effective technique seemed to be to keep the nozzle completely submerged and restrict the intake of any surface air.

Work described in Ref.(1) showed that a loosened potassium bicarbonate powder had an apparent density of 0.9 grams/cc. Since potassium bicarbonate has a density of 2.17 grams/cc, this meant that the bulk material standing in the can was already over one-half air and this was evidently almost enough to make it transportable in an air system. On one occasion the pick-up tube became blocked with a "solid" plug of powder. When this happened it was necessary only to shut off the vacuum. The powder then relaxed sufficiently for the nozzle to unplug and free itself.

After seven cans (350 lbs.) of P-K-P had been charged into the "air-lift" unit, (whose capacity has been rated by its manufacturer as less than 400 lbs. of Purple-K-Powder) the powder level was found to be 11 inches below the top. The apparent density of the material in the ball calculated to be 1.20 grams/cc, which was considerably higher than the 0.95 grams/cc normally resulting from the old method of filling powder through a funnel. If the filling were completed at the same density until full, it would be possible to charge 499. lbs. into the unit. The vacuum in the ball evidently removes a portion of the air normally accumulating between the powder crystals and thus, the higher apparent density results.

The amount of material which collected on the filter bag of the vacuum cleaner was weighed after emptying the five 50 lb. cans. A total of only 8.6 lbs. had been carried through the ball and into the vacuum cleaner. This was 3.4% of the total amount of powder picked up. It does not represent a true loss since this powder can be returned to the bulk of material being charged at any time during normal operation.

In order to determine the degree of powder classification (i.e., powder size separation) during the pneumatic process, the "before" and "after" powder samples were analyzed by the Blaine technique for specific area. The specific surface of the dry chemical (Purple-K-Powder) in the "as received" condition was 4,650 cm^2/gram; the value for the material charged into the "air-lift" unit was 4,400 cm^2/gram; and the value for the material carried through and collected on the filter bag of the vacuum cleaner was 11,580 cm^2/gram. These correspond to average particle sizes of 6.0, 6.3 and 2.4 microns, respectively.

DISCUSSION

The pneumatic filling operation described above was notable for its complete lack of attendant powder contamination of nearby operating personnel and surroundings. The phenomenally fast transport of powder to enable complete filling of a 400 lb. capacity "air-lift" unit in only approximately 6 minutes is a noteworthy advancement. Only an indeterminable and quite insignificant amount of dry chemical powder was lost by passing completely through the vacuum cleaner filter bag cloth. This material, of course, was exceedingly fine and remained in suspension in air as thin wisps of "smoke". If this pneumatic process of filling were to be conducted in an area where even a very small amount of this dust suspension was objectionable, the simple venting of the exhaust of the vacuum cleaner to the outside would completely remove all possibility of dust generation from the process.

Because of the fact that the very low 3.4% weight-amount of powder "carry-over" into the vacuum cleaner bag filter may be easily returned to the charging inlet tube before completion of the process, this does not constitute a material loss. However, this "carry-over" figure is probably influenced to a great extent by the volume of air (and its turbulence) being swept through the system. For this reason, it would be advisable to maintain a high powder-to-air ratio during operation by keeping the inlet tube of the pick-up nozzle well buried in the powder. Also, the continued free suction of air during changes

of powder container supply should be avoided by the simple mechanism of placing the palm of the operator's hand over the nozzle opening during such periods.

If, for some reason not evident at the present time, the low "carry-over" amount of 3.4% was to be considered excessive, some possibility exists that a centrifugal separating device such as the small tube separator made by Aerotech Industries, Inc., might reduce the amount of "carry-over".

It is difficult to assess the significance of the 5% change in specific surface of the powder resulting from the loss of some of the powder fines into the vacuum cleaner. There is no known fire extinguishing data on which the degree, if any, of reduced fire fighting capability could be determined by such changes. This separation of small particles is not believed to cause a resultant detectable change in fire fighting capability.

The final increased density of the powder being charged into the extinguisher insures that there will be no difficulty in getting the full, rated amount into the extinguisher. It is not high enough to cause compaction or to prevent proper extinguisher operation when the gas tube is of the proper design to produce loosening of the charge upon pressurization. A final charged density of 1.20 grams/cc in the extinguisher corresponds to the density of Purple-K-Powder dry chemical in a 30 lb. portable extinguisher after a period of normal vibration, Ref. (1). A degree of care will have to be exercised in this filling process to prevent overfilling with more than the rated charge. If the extinguisher is overfilled, it would not allow space for the powder bulk to expand to the apparent density necessary for good flowability and dischargeability. For this reason, the filling head is especially equipped with an access hole or port (See Fig. 1) into which a gaging rod may be inserted periodically for depth gaging of the powder contents. A fully charged 400 lb."air-lift" unit will show a powder depth at 14 inches from the gaging port level using the filling conditions described previously.

The particular size vacuum cleaner used in this work appears to be well suited in lift and flow capacity for the filling of the "air-lift" unit and the 150 lb. wheeled unit now used on aircraft fueling sites. The primary air moving element, being a four stage turbine, is not prone to damaging wear from the solids passing through it. This, in addition to the fact that the actual running time per year will be low, should insure a long lifetime for the vacuum cleaner. The model vacuum cleaner used in these tests (or similar cleaners) is carried as a Federal Supply item (FSC Group 79, Class 7910) and

this should simplify their procurement by local activities. Their estimated cost is $300. Incidentally, these units also have a great utility around firehouses as a piece of cleaning equipment. They can remove floor cleansing water as well as solid materials.

The fabrication of pneumatic fill system separator heads for the 400 lb. "air-lift" unit and the 150 lb. wheeled extinguisher is neither difficult nor expensive. Design specifications for its procurement may be easily finalized so that existing dry chemical units may be provided with this beneficial modification.

A simple modification of the standard fill-cap of the 150 lb. wheeled dry chemical extinguisher has been made so that it performs as an adapter to allow use of the separator head of Fig. 1 for vacuum filling this size extinguisher. (See Fig. 6) The standard 150 lb. fill cap was bored out and a bushing welded to it which had been fabricated with identical threads and O-ring slot as that on the 400 lb. unit.

A similar dry chemical extinguisher filling device and procedure should be developed for the large capacity multipurpose 4000 lb. dry chemical units for Antarctic use now under procurement, and for any large units contemplated in the future. Some increases in turbine size may be necessary for rapid powder transfer in large amounts. Attention might also be directed to the possibility of furnishing 400 lb. drum container sizes of dry chemical for large unit filling.

CONCLUSIONS

A simple and effective process for loading large capacity dry chemical fire extinguishing units has been developed, utilizing a pneumatic conveying system driven by a 1-1/2 horsepower industrial vacuum cleaner.

The system is capable of picking up 1.14 lbs./sec. of Purple-K-Powder dry chemical from its shipping cans and depositing it in an extinguisher shell. All container handling and hoisting, and all dusting nuisance normally associated with the dumping of powder from cans into an open funnel has been eliminated. The weight of powder lost is not measurable.

A reduction of 5% in the powder's specific surface value occurred because of separation of some of the powder fines during the pneumatic loading operation. No serious depreciation of powder efficiency is expected from this small change, whether it be returned to the extinguisher charge or not.

RECOMMENDATIONS

It is recommended that the equipment necessary to apply the pneumatic loading process described herein be obtained and suitable instructional procedures issued to enable field application of the system to existing large dry chemical fire extinguishing units in BuWeps or other activities.

It is further recommended that future procurements of large dry chemical units incorporate a similar pneumatic loading system to facilitate field operations of filling and refilling large extinguisher containers with powder.

REFERENCE

1. Peterson, H. B. and Gipe, R. L., "Discharge Characteristics of Potassium Bicarbonate Dry Chemical Fire Fighting Agents from Cartridge and Stored Pressure Extinguishers", NRL Report 5853, December, 1962

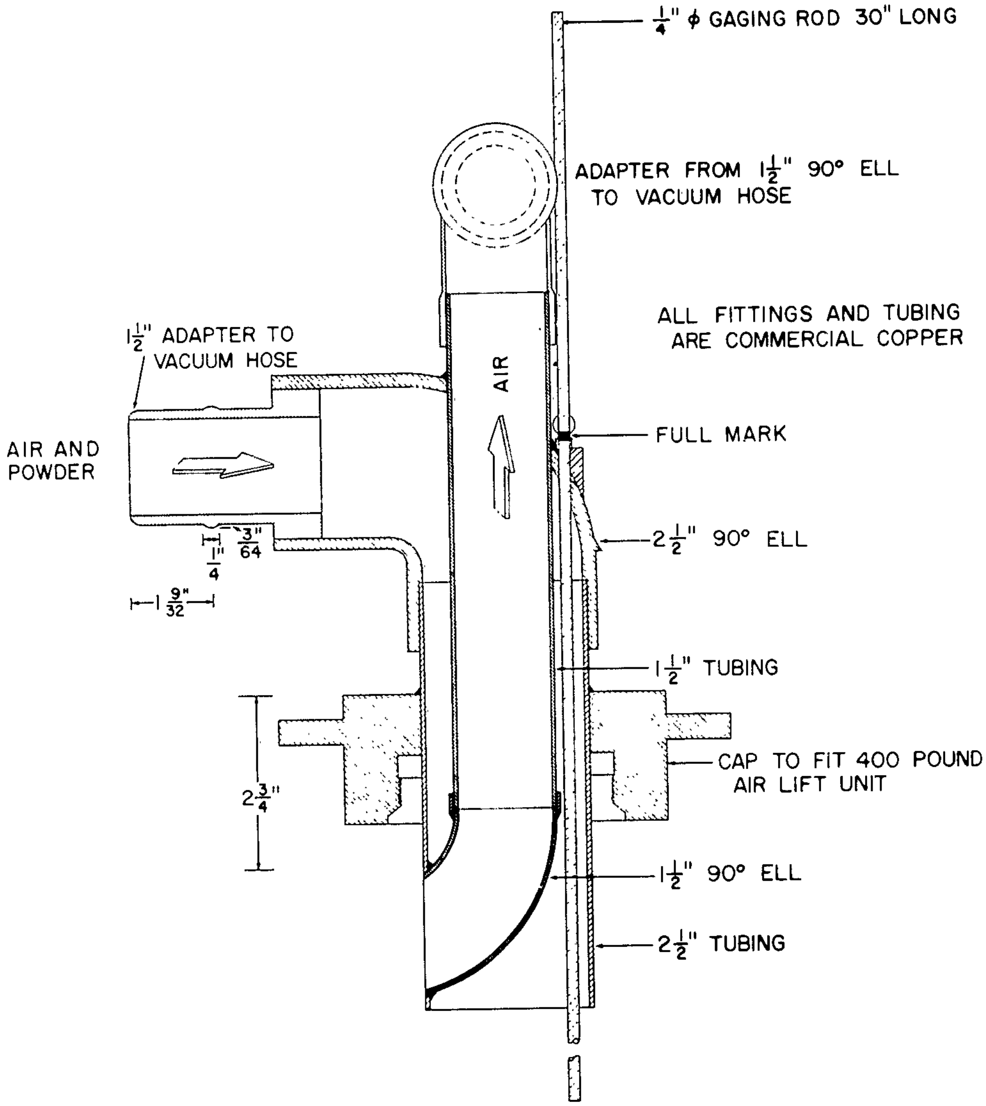

Fig. 1 - Cross sectional drawing of separator head construction

Fig. 2 - Photograph of head exterior, showing gaging rod

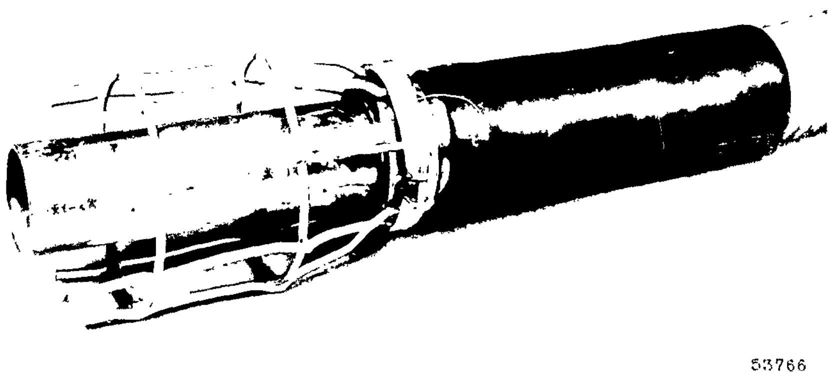

Fig. 3 - Powder pick-up nozzle

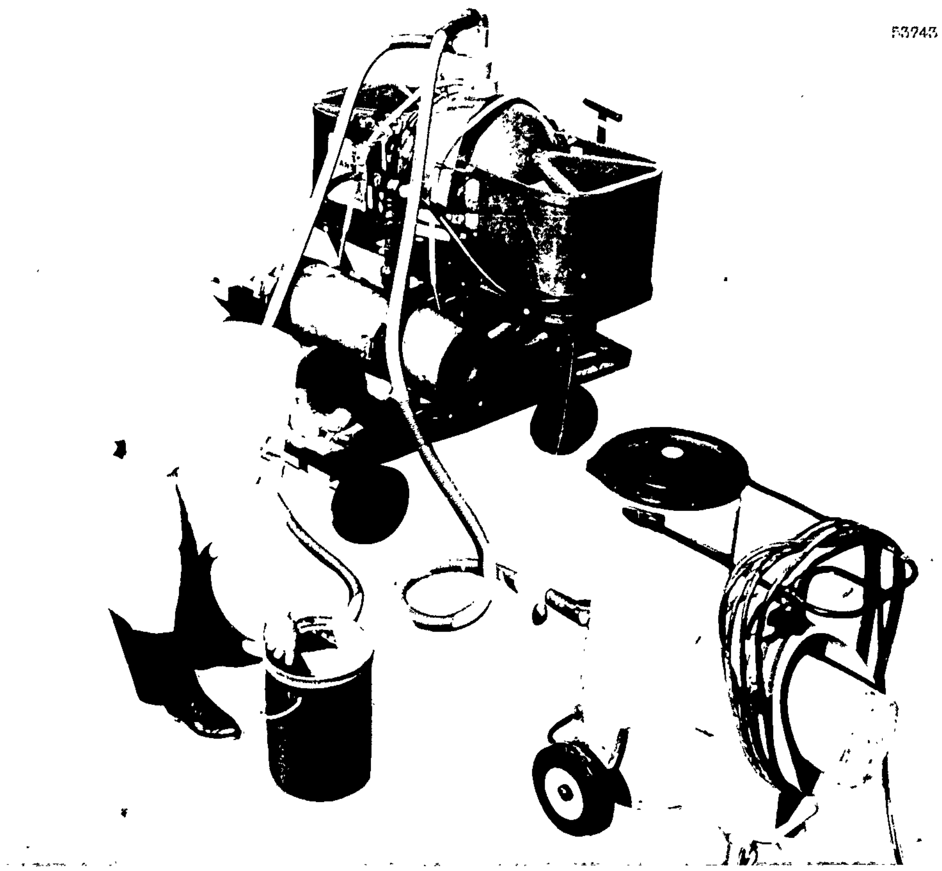

Fig. 4 - Overall view of pneumatic filling system in operation

Fig. 5 - Close-up of pick-up nozzle
moving powder contents of can

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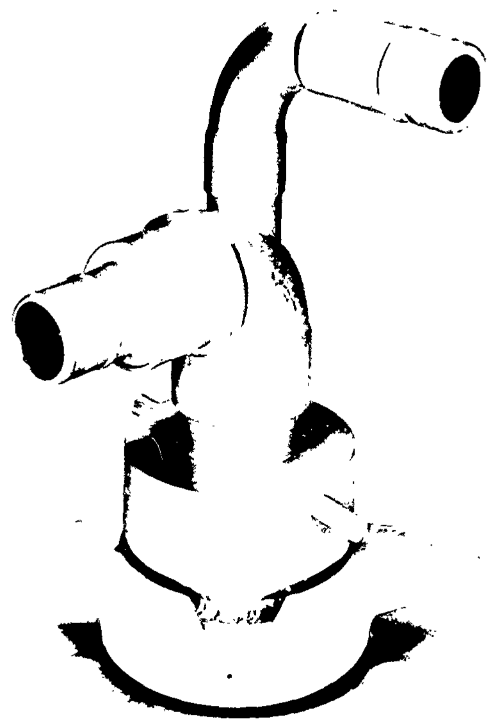

Fig. 6 - Adapter for fitting separator head to 150-lb. wheeled dry chemical extinguisher